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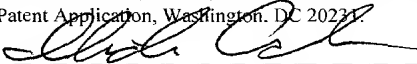
Case Docket No. XXT-063 (D/AO130)

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Sir:

Transmitted herewith for filing is the patent application of

Inventor(s): Sudhendu Rai, Ashok v. Godambe, Charles B. Duke, Guy H. Williams

For: PRINTSHOP RESOURCE OPTIMIZATION VIA THE USE OF AUTONOMOUS CELLS

Enclosed are:

- ☐ This is a request for filing a ☐ continuation ☐ divisional application under 37 CFR 1.53(b), of pending prior application serial no. \_\_\_\_\_ filed on \_\_\_\_\_ entitled \_\_\_\_\_.
- ☒ 8 pages of specification, 4 pages of claims, 1 pages of abstract.
- ☒ 7 sheets of drawings (Figures 1-7).
- ☒ A Declaration, Petition and Power of Attorney
- ☒ An assignment of the invention to Xerox Corporation. A recordation form cover sheet (Form PTO 1595) is also enclosed.
- ☐ A verified statement to establish small entity status under 37 C.F.R. 1.9 and 37 C.F.R. 1.27.
- ☐ Other \_\_\_\_\_

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PRINTSHOP RESOURCE OPTIMIZATION VIA  
THE USE OF AUTONOMOUS CELLS

## Technical Field of the Invention

5       The present invention relates generally to printing and more particularly to optimization of printshop resources via the use of autonomous cells.

## Background of the Invention

Conventional printshops are organized in a fashion that is functionally independent of print job complexity, print job mix, and total volume of print jobs. Typically, related equipment is grouped together. Thus, all printing equipment is grouped and located in a single locale. Similarly, all finishing equipment is grouped and located in a single locale. In other words, conventional printshops organize resources into separate departments, where each department corresponds to a type of process or operation that is performed to complete a print job.

When a print job arrives from a customer, the print job sequentially passes through each department. Once the print job is completely processed by a first department, the print job gets queued for the next department. This approach continues until the print job is completed. Unfortunately, this conventional approach leads to significant time delays and increased work-in-progress and inventory costs.

## Summary of the Invention

The present invention addresses the above-described limitations. In accordance with one embodiment of the present invention, a printshop is partitioned into autonomous cells. In addition, print jobs are partitioned into classes such that each autonomous cell contains sufficient resources to complete a print job of at least one class. Thus, for example, an autonomous cell may include equipment, such as multiple printers, a shrink wrapper and a computerized control system. A second autonomous cell may include different varieties of printers, cutters and copiers. The present invention intelligently divides the resources into autonomous cells and then assigns print jobs to the autonomous cells.

The assignment of print jobs to autonomous cells is done intelligently to provide desired load balancing and throughput. Moreover, print jobs are assigned to cells based on whether the cells have sufficient types of resource to complete the print job. The assignment of print jobs to the autonomous cells may be determined dynamically based upon the current queue of print jobs, current available capacity and current operating loads of the respective autonomous cells. The structure and composition of the cells



FIGURE 5 is a diagram depicting how a printshop is partitioned into four autonomous cells.

FIGURE 6 is a flow chart illustrating the steps that are performed to determine whether to reconfigure the autonomous cells of a printshop.

- 5       FIGURE 7 is a flow chart illustrating steps that are performed in determining whether to assign a print job to a particular autonomous cell in the illustrative embodiment.

#### Detailed Description of the Invention

- 10       The illustrative embodiment of the present invention provides an approach to partitioning resources in a printshop efficiently so as to optimize performance of the printshop. Printshop resources, such as printers, copiers, cutters, shrinkwrappers and other varieties of equipment, are partitioned into autonomous cells. When a print job arrives, it is assigned to a particular autonomous cell for completion. Each autonomous  
15       cell may act independently from the other autonomous cells in processing a print job. Print jobs may be partitioned into smaller-sized lots that are concurrently processed by autonomous cells in order to optimize the efficiency and throughput of each autonomous cell. Moreover, multiple print jobs may be processed concurrently by an autonomous cell, and multiple print jobs may be executed concurrently by multiple autonomous cells  
20       in parallel.

- Printshop resources are intelligently divided into autonomous cells. An analysis is made of print jobs that are typically performed by a printshop. Each type of print job is classified into a print job class according to the resources required to execute it. A print job class may be depicted graphically as a set of operations that are connected by  
25       edges representing the sequence of flow of operations in the print job. The capacity of each of the pieces of equipment in the printshop to perform operation is determined. The capacity for each print job class needed to meet the customer requirements is determined. The printshop resources may then be organized into autonomous cells and used during operation in an optimal fashion

- 30       Figure 1 shows a flow chart that provides an overview of steps performed in the illustrative embodiment of the present invention. Initially, the expected job flow in a printshop is collected and analyzed to determine the types ("classes") of jobs to be performed and the number of each per unit time (step 102 in Figure 1). The printshop is analyzed to design and propose autonomous cells into which the printshop resources  
35       may be divided so as to optimize the flow of jobs through the shop (step 104 in Figure 1). Each autonomous cell represents a grouping of one or more resources in the printshop that is capable of executing at least one class of print job. The autonomous

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If the results are acceptable (see step 108 in Figure 1), then a detailed cell layout is constructed (step 110 in Figure 1). The workflow within the print job is restructured to correspond with the cell layout. Scheduling algorithms are then constructed as well (step 112 in Figure 1). Once this is completed, the use of the autonomous cells becomes formally implemented (step 114 in Figure 1). The physical layout of the printshop may be restructured to account for the autonomous cells (step 116 in Figure 1).

Figure 2 is a flow chart illustrating steps that are performed to produce a graphical representation of the job flow in the printshop. This job flow depicts operations performed by resources in the printshop. Printshop resources include equipment, such as printers, copiers, rollers, shrinkwrappers, sealers and other varieties of equipment that are typically used to complete a print job. Those skilled in the art will appreciate that a wide variety of different types of equipment may be categorized as printshop resources, being included within autonomous cells in the illustrative embodiment. For example, manual resources may be partitioned as part of an autonomous cell.

35 In the illustrative embodiment of the present invention, the partitioning of the printshop into autonomous cells relies upon empirical data. The empirical data is gathered over a period of time, such as a few months or years, to identify the varieties of

A graphical representation of each print job class is developed by analyzing the flow between operations (step 210 in Figure 2). In particular, each print job operation is represented as a node and each edge constitutes a transition from one operation to a next that is required for a variety of print job class. Figure 3 shows an example of such a graphical representation of three varieties of print job classes. A first print job class is represented by nodes 302, 304, 306 and 312. These nodes 302, 304, 306 and 312 and the associated edges specify a sequence of operations to be performed to complete a print job of the specified print job class. A second print job class is represented by nodes 302, 304, 308 and 312 and the associated edges interconnecting these nodes. A third and final print job class is represented by nodes 302, 304, 310 and 312 and the associated edges.

Figure 4 shows in more detail the steps that are performed to design and propose autonomous cells (see step 104 in Figure 1). The job flow graph is partitioned into autonomous cells (step 400 in Figure 4). A suitable form of graph partitioning algorithm for performing this partitioning is specified in, "A concurrent approach to cell formation and assignment of identical machines in group technology," N. Wu, International Journal of Production Research, 1998, Vol. 36, No. 8; 2099-2114. Those skilled in the art will appreciate that the cells may also be partitioned using other techniques. The autonomous cells that result from the partitioning of the job flow graph are then mapped onto the physical layout of the printshop (step 402 in Figure 4).

Figure 5 shows an example of the partitioning of a printshop into autonomous cells. The printshop 560 shown in Figure 4 is partitioned into four cells numbered 1 through 4. Cell 1 includes printers 562, 564 and 566 and copiers 576, 578 and 580. Each of the copiers has an attached inserter 570, 572 and 574. A cutter 568 is also included in cell 1, as are computing resources 582, 584 and 586. The computing

resources may include server computers that execute software for automatically assigning print jobs to given cells and for processing print jobs once they have arrived in given cells. Moreover, the computing resources 582, 584 and 586 may provide the ability of operators to control operation of the equipment within the cell.

5 Cell 2 includes a computer system 592 and a highlight printer 590. Cell 3 includes a printer 594 as well as a sealer 598 and computer system 596. Lastly, cell 4 includes a shrink wrapper 503, a computer system 505, a printer 507 and a roll system 509.

10 The resulting partitioning and mapping of autonomous cells is evaluated by computer simulation (step 404 in Figure 4). The computer simulation attempts to simulate real-time printshop operation conditions. Certain constraints may be placed upon the autonomous cells. In step 406 of Figure 4, a determination made whether the constraints have been satisfied and whether the flow of operations between autonomous cells is minimal. In general, a cell should be self-contained such that there is no need for  
15 a cell to communicate with another cell in order to complete a print job. If the inter-cell flows are small and the constraints are satisfied (see step 406 in Figure 4), the resulting cell layout and job class mapping algorithm are utilized. On the other hand, if the inter-cell flows are not small and the constraints are not satisfied, the inter-cell flow metric is revised to capture constraints in a different way (step 408 in Figure 4).

20 Figure 6 is a flow chart illustrating the steps that are performed when a print job is received in a printshop that has been organized into autonomous cells. Initially, a print job is received at the shop (Step 602 in Figure 6). The submission of the print job may be performed by a customer walking into the printshop and making a verbal request for a print job. Alternatively, the print job may be received electronically. The  
25 specification of the print job identifies the tasks that are to be performed to complete the print job. This specification may also identify the timing required of the print job and particular features that are to be incorporated into the print job, such as type of printing to be used, type of stock to be used, whether binding is to be used and the like. The print job is analyzed to identify the operations that it requires and the quantity of  
30 operations that are required by the job (step 604 in figure 6). A determination is made whether the print job can fit into an existing cell (step 606 in Figure 6). If the print job will fit into an existing cell, a cost estimate and a schedule for printing the print job are prepared (step 608 in Figure 6). If the cost and the schedule are acceptable to both the printshop and the customer (step 610 in Figure 6), the job is accepted (step 614 in Figure  
35 6). If they are not acceptable to the printshop and/or the customer, the print job is rejected (step 612 in Figure 6). If the print job is accepted, it is assigned to an

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autonomous cell (step 616 in Figure 6) and subsequently sent to the autonomous cell (step 618 in Figure 6).

If in step 606 of Figure 6 it is determined that the print job does not fit into an existing cell, a determination is made whether it is feasible to have a new mapping onto the existing cells (step 620 in Figure 6). If it is feasible, such a mapping is performed so as to use existing cells (step 622 in Figure 6). If it is not feasible to map the print job onto the existing cells using a different mapping, an assessment of the print job value is made and an assessment is made of the reconfiguration cost which would be associated with reconfiguring the autonomous cells (step 624 in Figure 6). A cost estimate and schedule are prepared for performing the job in the reconfigured printshop (step 626 in Figure 6). If the cost and schedule are not acceptable to both the printshop and the customer (see step 628 in Figure 6), the print job is rejected (step 630 in Figure 6). In contrast, if the cost and schedule are acceptable to both the print job and to the customer, the printshop is reconfigured (step 632 in Figure 6). In particular, a new mapping of autonomous cells is generated. The print job is then assigned to one of the cells (step 634 in Figure 6) and sent to the associated cells (step 636 in Figure 6).

A number of different criteria may be applied to determine which autonomous cell to assign to a received print job. Figure 7 provides a flow chart illustrating an approach as adopted by the illustrative embodiment to the present invention. The cells may be examined in a predefined sequence, such as a round robin sequence or based upon utilization. For example, the process depicted in Figure 7 may initially begin with the least busy cell and continue with successively more busy cells until a suitable cell is found for processing the print job. Thus, initially, the cell of interest is examined (step 700 in Figure 7). First, a determination is made whether the cell has the proper resources for completing the print job (step 702 in Figure 7). For example, if a print job requires shrinkwrapping in the shop described in Figure 5 then cell 4 is used. Only cell 4 has a shrinkwrapper, and, thus, cells 1, 2 and 3 do not have the proper resources for completing the print job. A test may then be made whether the cell has sufficient available capacity to complete the print job within specified time requirements (step 704 in Figure 7). If a cell does not have enough capacity to print the print job in a timely fashion, then the cell may not be utilized to complete the print job. Those skilled in the art will appreciate that other criteria may also be applied (see step 706 in Figure 7) to determine whether to assign a print job to a given cell or not. In cases where the examined cells can not be used, a next cell is then examined (step 708 in Figure 7) until either it is validated that no suitable cell is available (step 707 in Figure 7) or until a suitable cell is found. If a suitable cell is found, the print job is assigned to the



Claims

- 5 1. In a printshop having resources for performing various tasks, a method,  
comprising the steps of:
- dividing the resources into autonomous cells, wherein each cell has  
sufficient resources to produce a print job; and
- 10 assigning each print job to a respective one or more of the cells for  
printing.
- 15 2. The method of claim 1 wherein the resources include equipment for performing  
printing tasks.
3. The method of claim 1 wherein the step of assigning print jobs comprises, for  
each given print job, determining what tasks need to be performed to complete the given  
print job and assigning the given print job to one of the autonomous cells that has  
20 resources for performing the tasks that need to be performed to complete the given print  
job.
4. The method of claim 3 wherein the step of assigning print jobs comprises, for  
each given print job, determining which of the autonomous cells has sufficient available  
25 capacity to print the given print job.
5. The method of claim 1 wherein at least one of the autonomous cells includes  
more than one machine for performing a same operation.
- 30 6. The method of claim 1 further comprising the steps of:
- determining classes of print jobs;
- 35 assigning each print job to one of the classes.

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16. A method of partitioning a printshop into autonomous cells, comprising the steps of:

identifying products produced by the printshop;

identifying operations required for producing each of the identified products;

determining printshop resources that are required for the identified operations;

determining a number of printshop resources required for operations to produce the products based on customer demand for products; and

partitioning printshop resources into autonomous cells based on the determined number of printshop resources required for operations to produce products based on customer demand for products, wherein each autonomous cell is independently capable of producing at least one of the identified products.

17. The method of claim 16 wherein throughput of each autonomous cell is determined as a function of the printshop resources allocated to the autonomous cell, and wherein the printshop resources are allocated to each autonomous cell based on customer demand.

18. The method of claim 16 wherein the step of identifying products comprises identifying classes of print jobs produced by the printshop, wherein each class includes a sequence of operations that is performed for print jobs of the class that differs from the sequence of operations performed for each of the other classes.

19. The method of claim 16 wherein customer demand is estimated based on empirical data.

20. The method of claim 16 further comprising the step of assigning a print job to a selected one of the autonomous cells for completion by the selected autonomous cell.

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21. The method of claim 20 further comprising the step of dividing the print job into smaller sized lots and concurrently processing the smaller sized lots in the selected autonomous cell.
- 5 22. The method of claim 20 wherein the assigning step is performed by a computer system.

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A printshop contains resources that are utilized to complete print jobs. The resources are partitioned into autonomous cells. Each autonomous cell is capable of completing at least one class of print job. Print jobs are assigned to the autonomous cells for completion. An autonomous cell may subdivide a print job into smaller sized lots and process the smaller size lots in parallel. This approach enhances the efficiency of the shop, decreases the work in progress, labor and inventory costs associated with running the print jobs and increases the utilization of the printing equipment in the printshop.





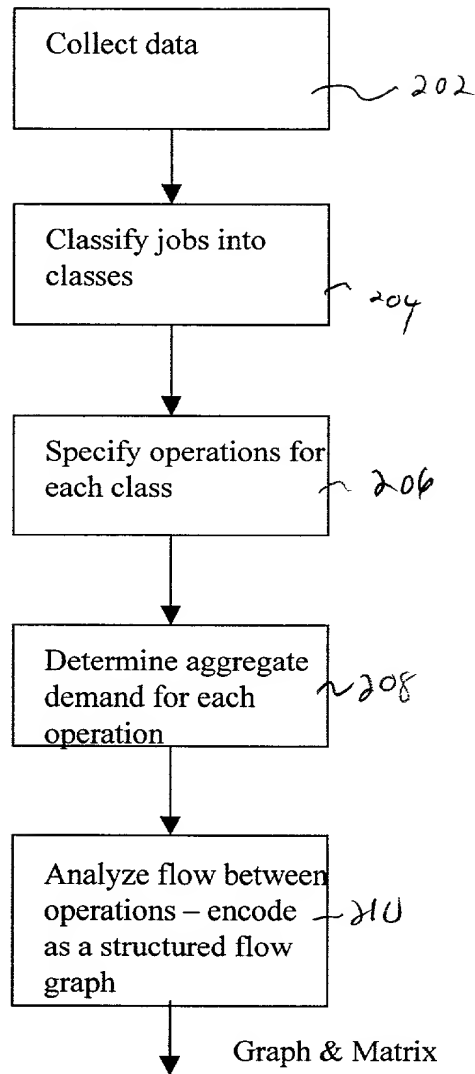


Figure 2

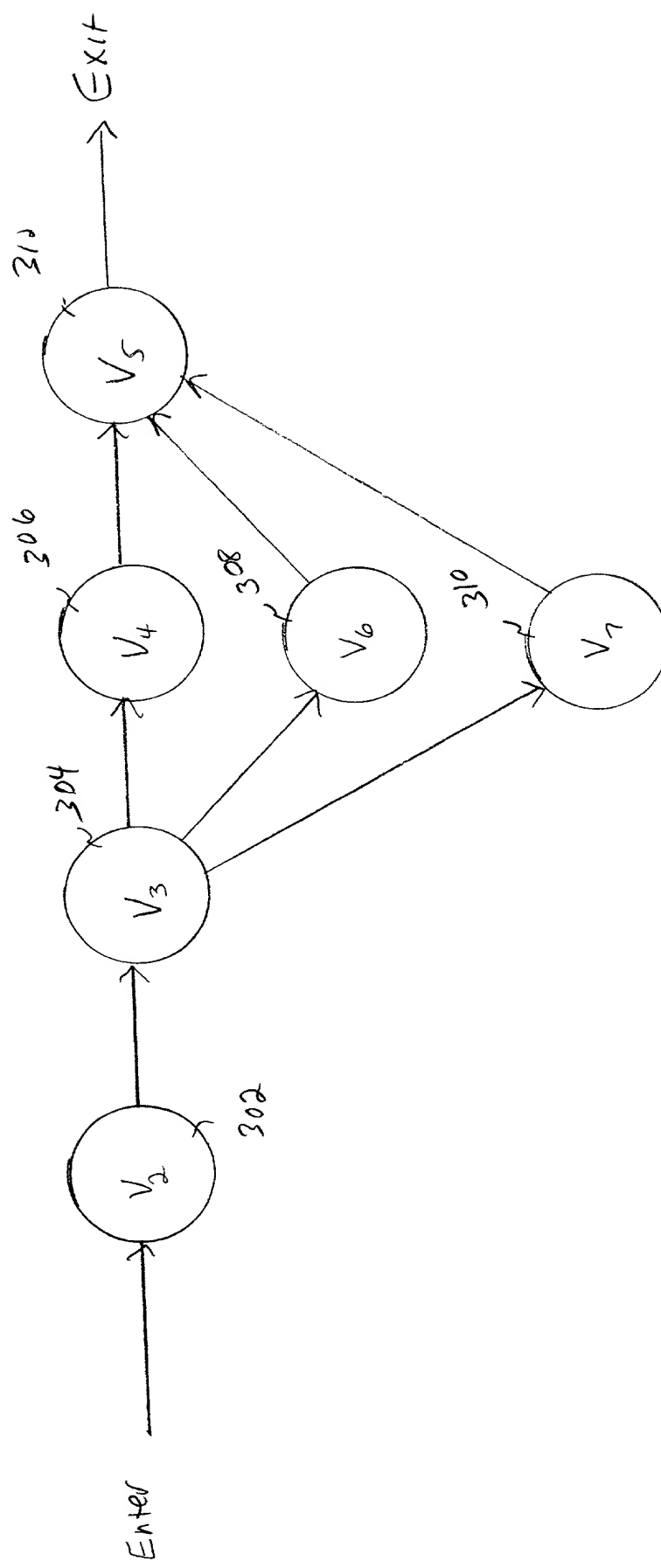
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Figure 3

$\sim 400$

Map onto physical layout

402

Revise intercell flow metric to capture constraints in a different way

~ 408

Evaluate by simulation

~ 404

No

~~Intercell flows small  
& constraints satisfied?~~

Yes

- Cell layout
- Job class mapping algorithm

Figure 4

5100

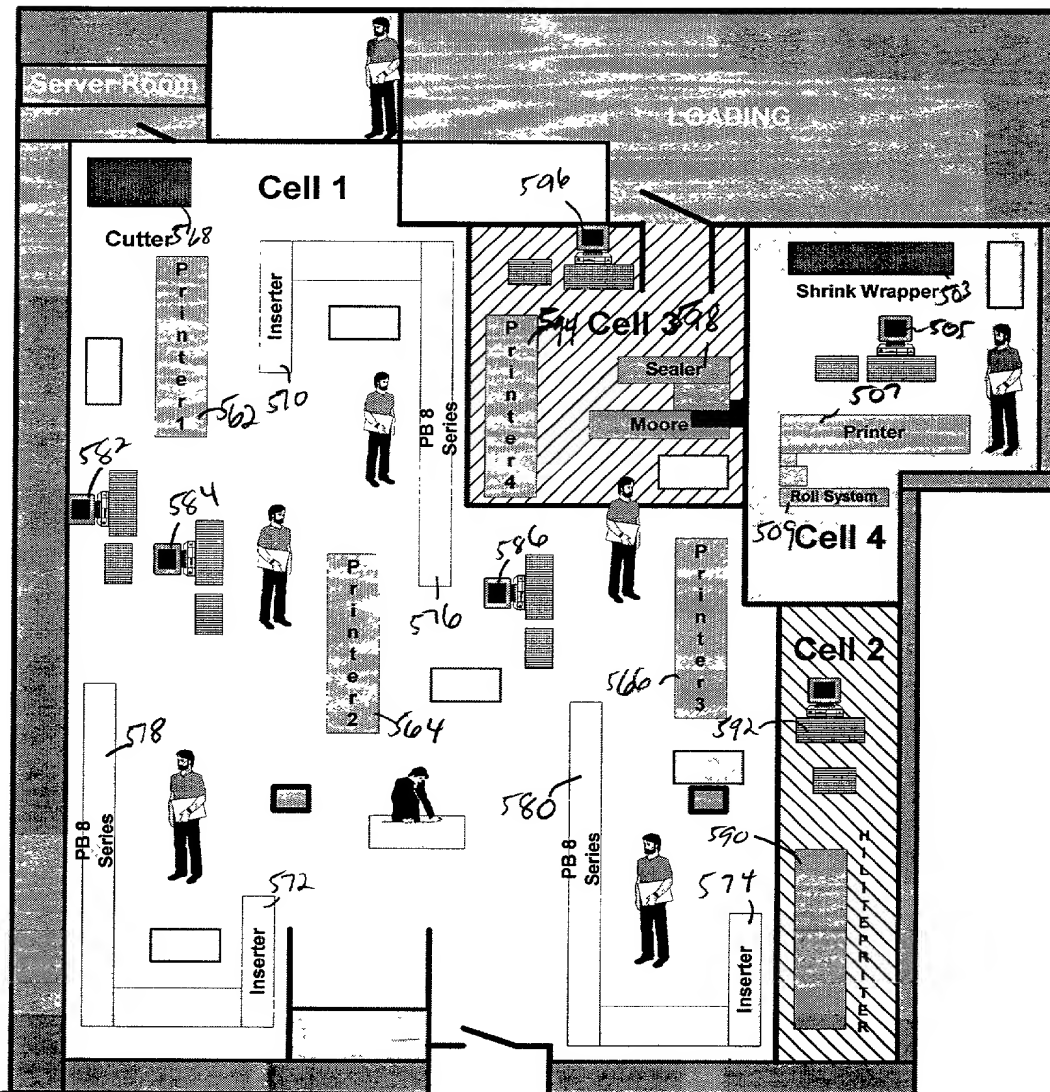


Figure 5

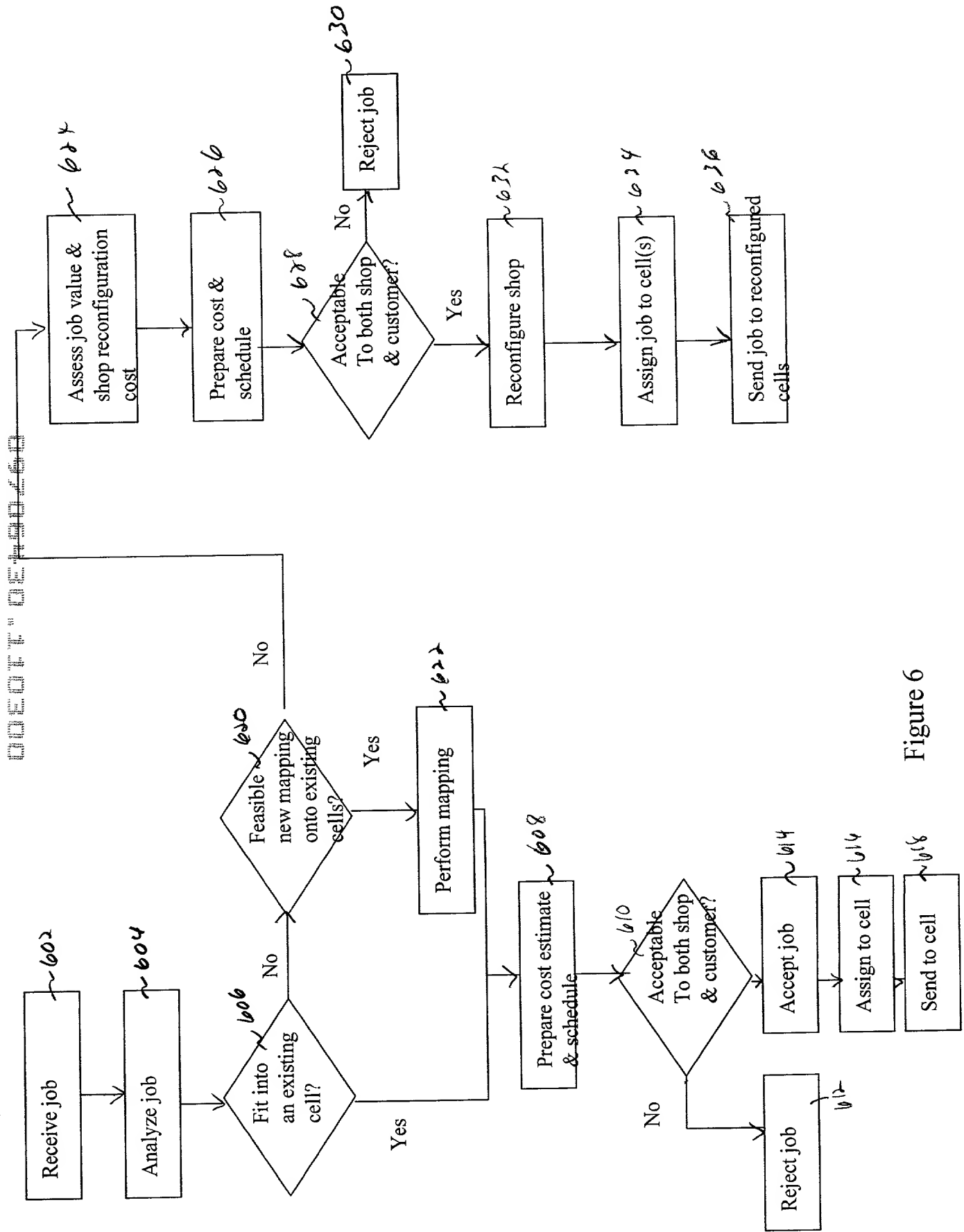


Figure 6



Number XXT-063

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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